Diamond and Diamond-like Carbon Coatings in Diesels

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Current diesel engines have evolved over the past century, but are still water cooled, oil-lubricated (synthetic or petroleum product), and essentially fabricated from steel. The next generation of diesels will operate at higher temperatures, stresses/loads, and speeds to achieve the higher thermal efficiencies and power densities required for improved fuel mileage. The durability of engine components at higher operating temperatures and stresses will be severely limited and require the use of new materials (steels, alloys, ceramics, and composites) that are not proven in terms of their friction, wear, and lubrication properties. New strategies are therefore needed to lubricate the new materials that are being selected including:

- Development of wear-resistant, high-temperature, high strength-materials (ceramics, alloys, steels, and composites).
- Development of surface modification treatments that permit optimization of material selection based on bulk properties (mechanical strength, etc.) and surface properties (e.g. friction, wear, and lubrication).
- Development of new lubrication strategies compatible with new high-temperature materials and surface-modification processes.
  - Low-cost, low-viscosity synthetic liquid-lubricant base stocks capable of surviving at elevated temperatures.
  - High-temperature liquid lubricant additive packages (dispersants, acid neutralizers, detergents, metal deactivators, and anti-wear agents).
- Development of solid lubricants (either as coatings or oil additives) to enhance boundary lubrication behavior of low-viscosity (fuel-efficient) liquid lubricants.

Argonne National Laboratory is developing and evaluating advanced low-cost, high-production-rate surface modification processes to deposit ultra smooth nanocrystalline diamond and amorphous diamond-like carbon (DLC) coatings that have excellent friction, wear, and lubrication properties.

Ongoing research indicates that ultra smooth nanocrystalline diamond coatings can significantly reduce wear of ceramic seals exposed to abrasive waterborne particulates found in engine coolants. Research on amorphous DLC coatings deposited at low temperatures on ceramic and steel components indicate they would be extremely effective in fuel-injection components that are being designed to run on alternative fuels (e.g. DME) that are lower in viscosity and more corrosive than diesel fuel, or operate at higher pressures and temperatures. DLC coatings are also being examined as wear-resistant coatings for other engine components (e.g. rings, bearings, gears, etc.) that incur boundary-lubrication conditions.

Efforts are currently underway to commercialize the diamond and DLC technologies developed at Argonne. For custom seal applications, efforts are focusing on scaling-up ANL's nanocrystalline processes to cover large seal areas. Nanocrystalline diamond films are also being considered for low-cost, mass-produced diesel seals where the cost of an ultrasmooth nanocrystalline diamond film that can extend seal lifetimes beyond the warranty (typically 250,000 miles) lifetimes can be justified to reduce/eliminate warranty repair costs that are up to a 100 times that of the seal. Efforts are also ongoing to develop and commercialize low-cost, high-production rate processes to deposit DLC coatings on fuel injection components. This work is focusing on the use of vacuum-processing technologies (e.g. ion-nitriding/carburizing) that are currently accepted manufacturing processes capable of handling large numbers of components on an economical basis.

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